b. Risk Characterization

(I) Fate and transport of phorate and phorate metabolites

Surface and ground water contamination may occur from the *sulfoxide and sulfone degradates of phorate, as well as from parent phorate*. However, the risk of water contamination is *primarily associated with phorate sulfone and phorate sulfoxide* rather than parent phorate, based on higher persistence and mobility of the degradates.

Phorate itself (*parent phorate*) is *not persistent* in the environment. It has been shown to degrade in soil by chemical and microbial action and to dissipate in the field with half-lives of 2 - 15 days. It is *moderately mobile* in soil, and has been shown to leach to a maximum depth of 6 inches in loamy sand and sandy loam soils. Phorate is subject to rapid hydrolysis with a t1/2 of about 3 days. Due to the limited migration and the rapid hydrolysis, parent phorate is not expected to pose a significant risk to ground water. In contrast to phorate, the *phorate degradates*, phorate sulfoxide and phorate sulfone, are both *more persistent and more mobile* in the environment.

(ii) Terrestrial Risk Characterization

Exceedances of Ecological Concern Levels. For terrestrial species acute Levels of Concern (LOC) are exceeded for all species, crops, and applications rates. The greatest exceedances were calculated for small mammals. Risk Quotient values greater than 1000 were obtained for broadcast applications for corn and hops, banded or in-furrow for potatoes, and banded or in-furrow for radishes. For mammals whose body weight approximates 1000 g, the RQs range from 22 for broadcast use for corn and hops and side-dress radishes to 0.5 for banded or in-furrow use in wheat.

Avian RQ values ranged from about 600 for songbirds in broadcast use in corn and hops to 0.5 for upland gamebirds for soil in-furrow use in wheat. The risk quotient values suggest that songbirds are the birds most at risk: the RQ value ranged from two to three orders of magnitude greater than the level of concern for all uses and all application methods.

Chronic risk quotients for reproductive effects have not been developed for birds. A mallard reproduction study with a reported NOAEL of 5 ppm indicates high toxicity on a chronic basis. The potential for adverse chronic effects on birds is discussed further below.

Field information on avian risk, including incident information. Simulated field studies, as discussed in the ecological toxicity data section, confirm the toxicity and exposure estimates. They also suggest that contaminated water may be a route of exposure. All four bobwhite quail pen studies show mortality, even though quail are not the most sensitive species based on the LD50 studies. Mallard duck, red-winged blackbird, and common grackle are all more sensitive. Both whorl and soil application resulted in adverse effects. There is additional exposure to birds in the turn row areas, increasing the overall risk to birds. At the rate of 6 oz per 1000 row feet, 71 granules per square foot were found in the row, while over twice that many were found in the turn rows (150 granules per square foot).

Incident reports which describe fatalities to birds and mammals support the conclusion that Phorate use poses a risk to wildlife. A wide range of species was affected in the reported incidents. (See Section C.4.a and Appendix C.1.)

The incident information suggests that poisoning of wildlife by phorate and/or phorate degradates may occur several months following application. Fall applications in cool climates may pose a particular hazard. In particular, there are three incidents supporting high avian risk associated with fall applications for winter wheat. Of these, two occurred months after application. (See additional discussion in Section C.4.a.)

The incident record suggests a tendency for waterfowl to be affected directly. This may be consequence of slow degradation in wet parts of a field, due to some combination of anaerobic soil conditions associated with waterlogging, and (in the case of fall applications, particularly in S. Dakota) relatively low temperatures associated with application late in the year. During spring, puddles will form in low-lying parts of a field. Waterfowl will enter shallow water and disturb sediments by feeding, possibly causing release or ingestion of any phorate residues that have persisted, and oral and/or dermal exposure of the waterfowl. Alternatively, phorate residues may be washed by spring rains into low-lying areas from other parts of a field, where puddles will form and waterfowl gather. The possibility of exposure may be particularly severe in S. Dakota if phorate residues persist into winter, because the soil may become frozen, limiting dissipation by leaching as well as by degradation.

This suggests that direct involvement of phorate metabolites may be more significant than involvement of parent phorate, which tends to degrade more rapidly. Phorate sulfoxide and phorate sulfone are OP chemicals, which suggests that they may be toxic. However, toxicity measurements are not available at this time for phorate metabolites.

EFED suggests that these generalizations derive some support from incidents with greater indications of "misuse," relative to the incidents listed above. Winter wheat incidents occur in multiple states and years. The incidents tend to involve waterfowl and tend to involve wetland areas more than permanent water bodies. Even if it is assumed that 100% of winter wheat incidents are due to "misuse," EFED suggests that it is desirable to determine why winter wheat, which accounts for a small percentage of phorate use and a high percentage of phorate avian incidents, is prone to being misused in a way that leads to the specific pattern of incidents indicated.

The information available to EFED at this time suggests that incorporation of phorate into soil is likely to reduce exposure to wildlife. Exposure to wildlife may also be limited if phorate is not allowed to wash into parts of a field that tend to remain wet, and if phorate is applied early enough in the year for phorate residues to degrade more completely.

Wildlife ingestion of granular pesticides. Wildlife may ingest granular pesticides by mechanisms that include (1) "intentional" ingestion of granules for grit by birds; or (2) incidental ingestion of phorate or phorate metabolites along with food (ingestion of phorate granules and/or contaminated soil or sediment); (3) drinking water contaminated with phorate or phorate metabolites; and (4) preening or grooming.

Consumption of granules depends on their availability, bird behavior, characteristics of grit preferred by birds, and grit retention in the gizzard (Best and Fischer, 1992). Evidence from insecticides other than phorate indicates that birds feeding on soil invertebrates brought to the surface during planting and application may ingest 3 or 4 granules adhering to an insect or grub. Various species of birds including waterfowl will ingest some soil in the course of foraging. A severe incident for terbufos occurred in Texas in 1996 when hawks ingested soil while feeding opportunistically on grubs.

Some small mammal species may be particularly vulnerable to granular pesticides because of close association with soil. Mammals are more sensitive to phorate than birds on a dietary basis: The lowest mammal LC50 is 28 ppm and the lowest avian LC50 is 248 ppm.

Assessment of hazard of granular pesticides to wildlife. Exposure of nontarget organisms, particularly birds, to pesticide granules is assumed to be related to the application rate and number of granules present on or near the soil surface. All application methods for granular formulations will result in the presence of some granules at or near the soil surface, where they are accessible to foraging wildlife. Both band and in furrow application of granular pesticides using conventional commercial application equipment result in exposed granules on the soil surface. In a laboratory soil study using a variety of incorporation techniques and several models of planters operated at different speeds, Hummel (1983) found granule incorporation ranged from 69% to 96% for band application, and generally 99% for in-furrow application. Erbach and Tollefson (1983) found that an average of 15% of the granules remained visible when no incorporation other than a press wheel was used.

These percentages of visible granules probably underestimates the actual number of granules remaining, because granule counts were within rows and did not include row ends. Also, the fluorescent techniques used to observe granules were not 100% efficient, and thus did not allow the identification of all granules (Tollefson 1979). In addition, the number of granules found in turn areas at row ends (where application equipment is raised from the soil) would be considerably higher than along row areas where granules are incorporated.

The number of lethal doses (LD50s) that are available within one square foot immediately after application (LD50s/ft^2) is used as the risk quotient for granular products. Risk quotients are calculated for three separate weight class of birds: 1000 g (e.g. waterfowl), 180 g (e.g. upland gamebird) and 50 *g* (e.g. songbird). surface. Support for this approach can be found in the literature. DeWitt (1966), after conducting a quail field study, concluded, "Losses of birds may be expected if the quantity of toxicant per square foot equals or exceeds the quantity causing deaths of quail in short term feeding tests."

Phorate granules are probably relatively hazardous to birds for the following reasons:

1. Only 3 or 4 granules are necessary to equal the lethal dose. These calculations are supported by Balcomb et al. (1984). He gave red-winged blackbirds 1, 5, and 10 granules of Thimet 15G at 5 granules 60% of the birds died and at 10 granules 80% of the birds died.

2. The number of granules per square foot is relatively high (500 to 667 granules per sq. ft.) considering the few granules needed to be fatal.

Avian dermal exposure. Dermal exposure may play an important role in poisoning. An example of typical bird behavior where dermal exposure is likely would be birds dusting themselves.

It is likely that where phorate contacts the skin it will be absorbed. In particular, for many birds dermal uptake may be very efficient in the skin located where the wing meets the body, because that area of skin is bare in many bird species. Tests with parathion revealed dermal toxicity results that were very similar to oral toxicity results (Schafer et al. 1973), when the skin under the wing was exposed.

Human incidents suggest that dermal and inhalation poisoning are likely. These incidents usually do not involve oral exposure. The victims are usually handling the product, e.g., loaders and applicators. Toxicity data indicate that dermal and oral toxicity are similar. If mammals are a surrogate for birds (oral LD50=0.62 mg/kg) the mammal dermal LD50 is nearly the same as the oral LD50, 3.9 and 1.4 mg/kg, respectively.

However, for birds Hudson et al. (1984) performed a 24 hour percutaneous LD50 with one year old mallard hens and the 88% technical product. This dermal foot treatment indicated that for this route of exposure the LD50 was 203 mg/kg which is in the moderately toxic range. The exposed skin under the wing may be more likely to absorb the chemical that the feet. The two tissues (foot skin and skin under the wing) are very different and dermal exposure cannot be discounted at this time. Dermal exposure may or may not contribute significantly to total avian exposure for phorate.

Effects on wildlife food chains. Dieter et al. (1996) applied phorate to mesocosms at rates intended to simulate runoff or direct application to tilled wetlands. They found that amphipods and chironomids were affected for 1 month at applications rates as low as 1 pound per acre. (The application rate of 1 lb ai/A corresponded to a median concentration of 23 µg/L one day after treatment in the water and higher concentrations in sediment.) These invertebrates are an important food source for waterfowl. Dieter et al. also reviewed studies of the effects of various insecticides other than phorate on birds in the prairie pothole region. Various studies have associated decreased abundance of food with abandonment of nests, emigration from or reduced use of treated wetlands, or decreased growth rates.

Chronic avian risk. Although risk quotients for chronic/reproductive effects have not been developed the following considerations indicate that there is a potential for adverse effects.

• Reproductive effects (eggs laid, viable embryos, and normal hatchling) are seen at low dietary levels. The toxicity information for mammals suggests that the phorate sulfoxide metabolite may be more toxic on a chronic basis than parent phorate. A 90 day rat feeding study shows that phorate sulfoxide has a lower NOEL than phorate, 0.66 ppm for phorate and 0.32 ppm for phorate sulfoxide. In both studies cholinesterase inhibition was the endpoint. Other phorate degradates that retain the organophosphate structure, phorate sulfone, phorate oxygen analog, phorate oxygen analog sulfoxide, and phorate oxygen analog sulfone metabolites are expected to also exhibit cholinesterase inhibition.

• Data on preharvest intervals indicate that 30 days is required for residues in treated corn plants to reach a level below the tolerance level (0.1 ppm for phorate).

• Studies with organophosphate pesticides other than phorate have shown that negative effects on avian reproduction can result from exposures of short durations, e.g., 8-10 days (Bennett and Ganio, 1991). Bennett and Ganio (1991) mention effects on egg production, eggshell quality, incubation, and brood-rearing behavior.

• Terrestrial incident information indicates phorate residues persisting for weeks or months following application, at levels that caused adverse effects in birds.

(iii) Aquatic Risk Characterization

All acute risk quotients exceed high risk criteria and most chronic risk quotients exceed levels of concern. The exception is for the potato scenario involving in-furrow application. For that scenario, the exposure modeling results suggest negligible exposure. However, EFED is not confident that the incorporation options in the current version of the PRZM model adequately represent availability of pesticide for in-furrow applications.

Field studies and incidents confirm risk to aquatic organisms. We find that there are two aquatic incidents probably associated with phorate use (B000150-001,002; B000150-001,003). A pond study reported did not produce results that could refute a significant ecological risk.

Some of the terrestrial incidents suggests hazard to birds foraging in puddles in early spring, from phorate applied in the preceding fall (e.g., to winter wheat). These incidents suggests that phorate and/or phorate metabolites may be present in a critical time window for amphibian breeding in early spring. The Agency does not have information on toxicity of phorate to amphibians. The ecotoxicity information available for fish (considered the best surrogates) suggests very high acute toxicity.